



U.S. ARMY TANK AUTOMOTIVE RESEARCH, DEVELOPMENT AND ENGINEERING CENTER

# Lightweight Combat Vehicle S&T Initiatives

Global Automotive Lightweight Materials 2015 – August 18-20 2015

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## MISSION:

Develop, integrate and sustain the right technology solutions for all manned and unmanned Department of Defense(DOD) ground systems and combat support systems to improve Current Force effectiveness and provide superior capabilities for the Future Force.

## VISION:

The first choice of technology and engineering expertise for ground vehicle systems and support equipment – today and tomorrow.

**We help our Warfighters succeed and come home alive**

# Organizational Structure



**AMRDEC**  
Aviation and  
Missile  
Research  
Development  
and  
Engineering  
Center



**ARDEC**  
Armament  
Research,  
Development  
and  
Engineering  
Center



**ARL**  
Army  
Research  
Laboratory



**CERDEC**  
Communications-  
Electronics  
Research,  
Development  
and  
Engineering  
Center



**ECBC**  
Edgewood  
Chemical  
Biological  
Center



**NSRDEC**  
Natick  
Soldier  
Research,  
Development  
and  
Engineering  
Center



**TARDEC**  
Tank  
Automotive  
Research,  
Development  
and  
Engineering  
Center

## We Need An Expeditionary, Scalable & Ready Modern Army (From CSA Priorities, SEP 13)

- Focus S&T investment to maximize the potential of emerging game-changing land power technologies to counter emerging threats.
- Rapidly deploy, fight, and win whenever and wherever our national interests are threatened.
- Train and equip the Total Army to rapidly deploy, fight, sustain itself, and win against complex state and non-state threats in austere environments and rugged terrain (The expeditionary mindset).

**But what does the future force look like?**

**Weight reduction is a key enabler for an expeditionary force**

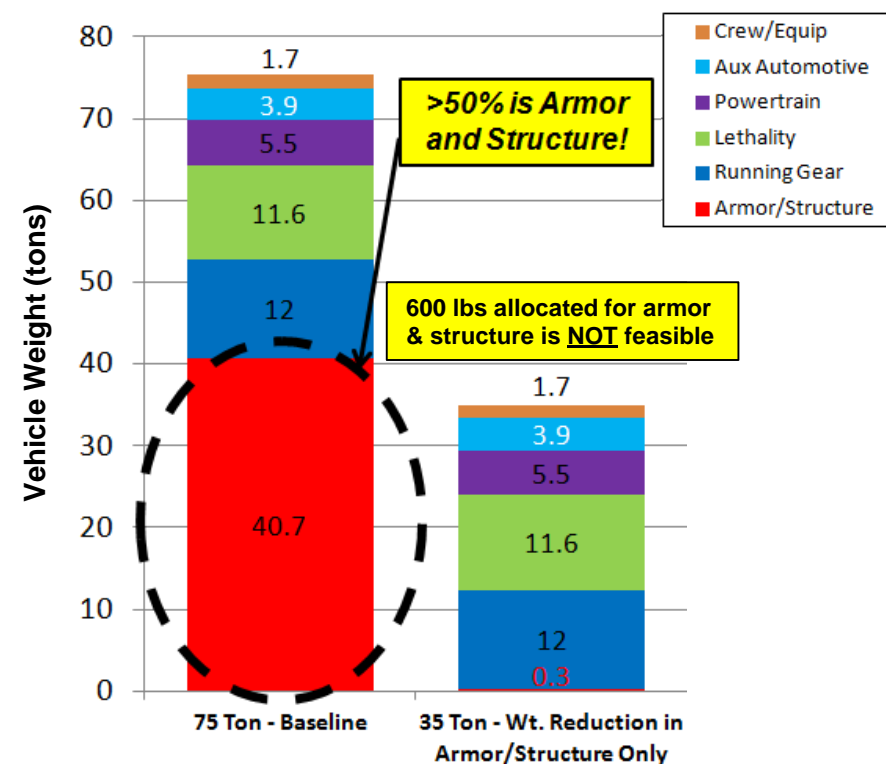
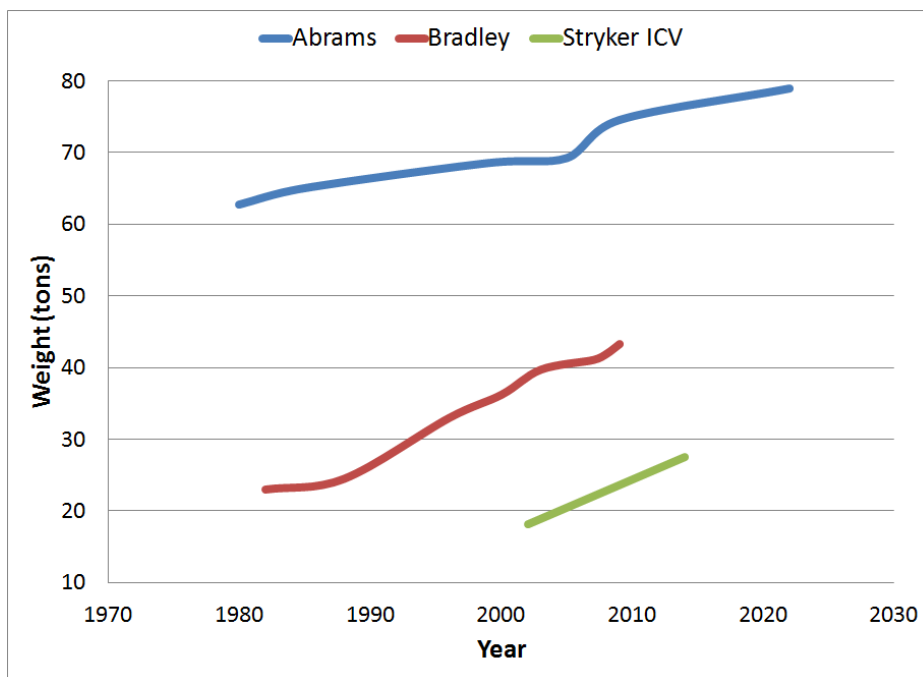
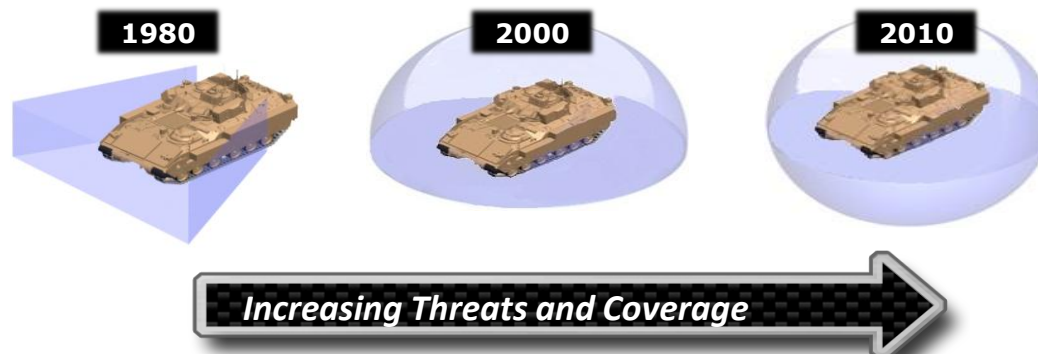


**Deploy globally and rapidly; seize & maintain initiative without sacrificing protection**

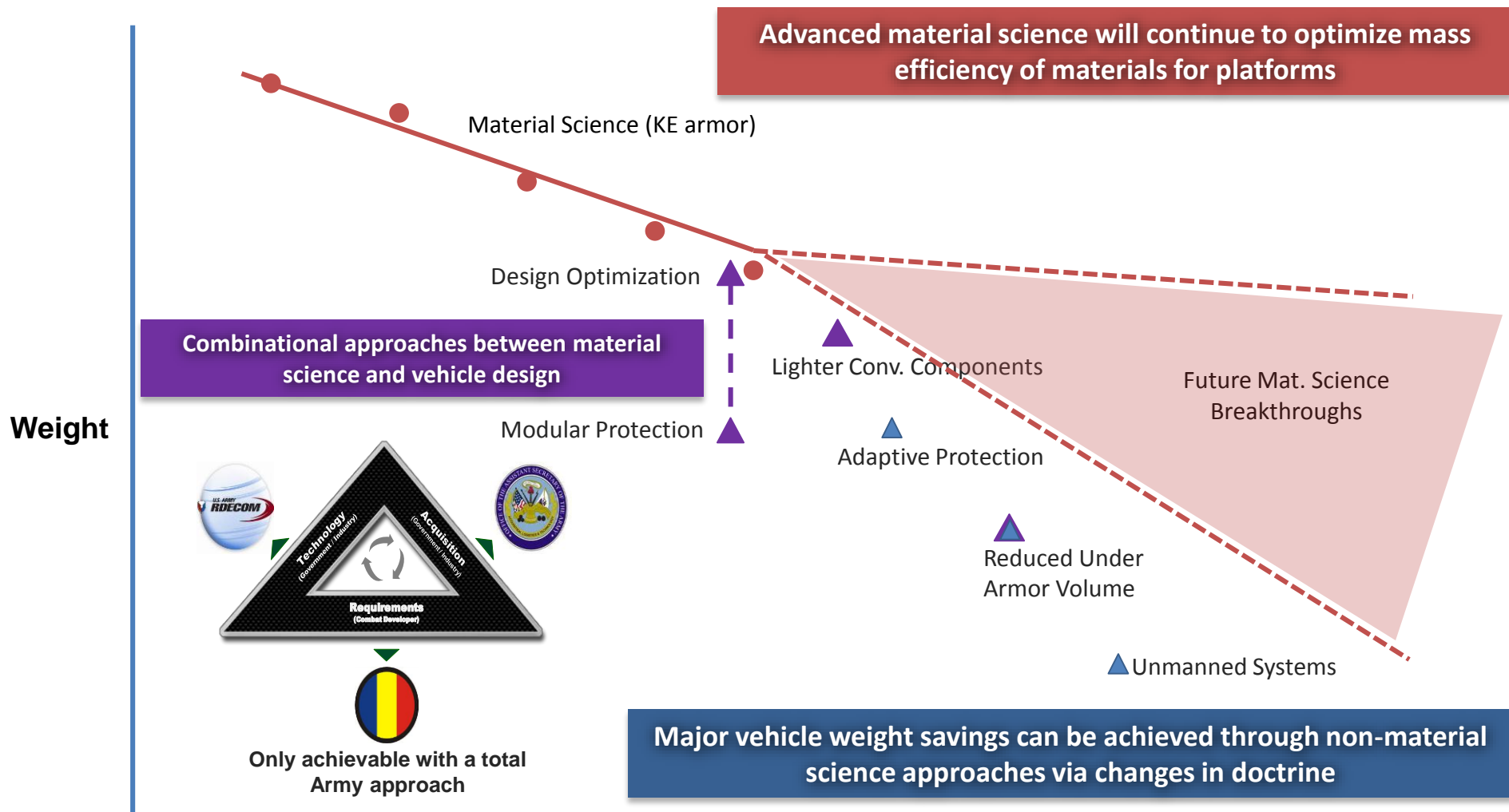
# Challenge: Reducing Weight w/Increasing Threats



Vehicle weights have risen in response to new and increasing threats and increasing vehicle protection areas



# Weight Reduction Opportunities



**Achieving the Army's goals for light-weight ground vehicles relies on the integration of both material and non-material science approaches**



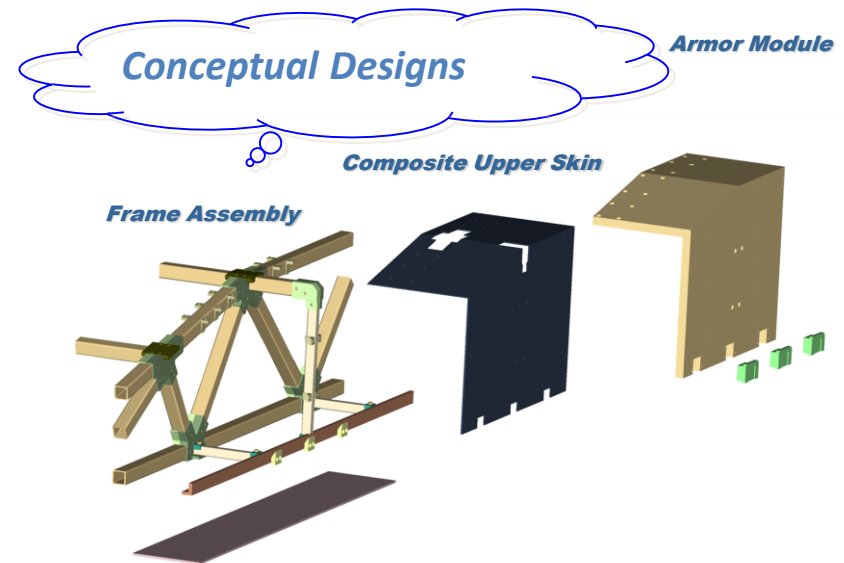
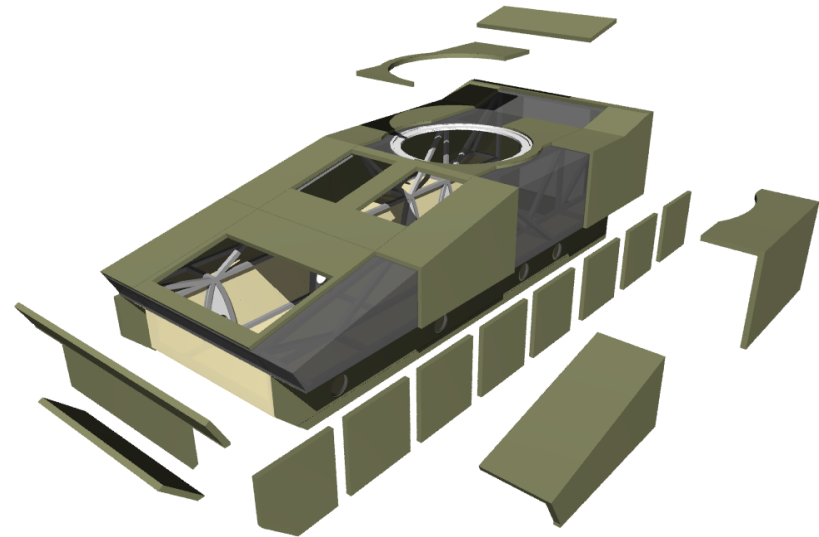
### Vehicle Sub-system



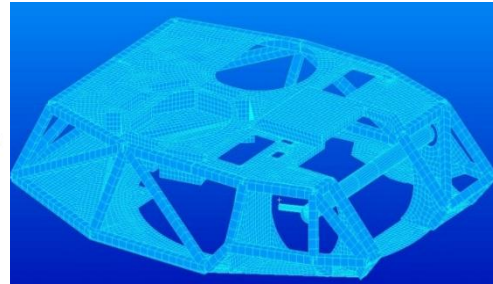
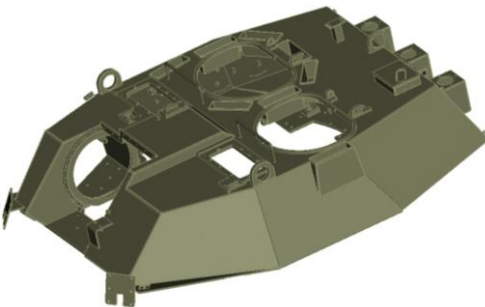
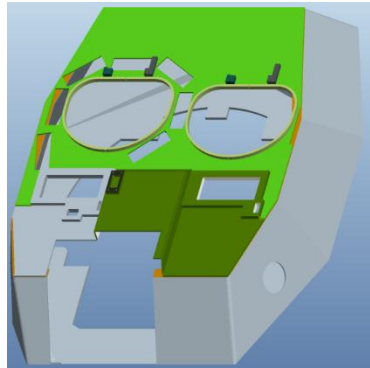
# Issues to Lightweighting Combat Vehicles



- Development of survivable vehicle systems while keeping to air transport weight.
- Attachment methodologies for A + B + C armor concept, appurtenances
- Joining and fastening technologies (dissimilar materials), adhesives
- Balancing interior volume against the use of less efficient structural material solutions
- Signature management, electromagnetic shielding over potentially non-metallic surfaces
- Diagnostics & prognostics for structural health assessment
- Material costs and improving multi-hit performance
- Advanced structures offer part consolidation necessitating development of high yield mfg. processes
- Inspection and repair of advanced armor systems
- Improved modeling and simulation



# Light-Weight Vehicle Structure (LWVS)



## PURPOSE

- Demonstrate best practices in affordable, multi-material design for structures to reduce ground vehicle weight
- Utilize automotive technology investments in vehicle structure light weighting
- Demonstrate a weight savings of up to 400 lbs on a testable LAV-25 without degradation in performance.
- Evaluate the current technical capability of the supply chain.

## ARMY PAYOFF

- Increased fuel economy
- Increased reliability
- Greater SWAP-C (Space, Weight, Armor, Power, Cooling)

## RESULTS / PRODUCTS

- 400 lbs lighter multi-material turret (<1,000 lbs turret structure)
- Bi-metallic cast trunnion
- Affordable (targeted for future upgrade)
- Updated production cost models

## Architecture

- Armored roof
- Carbon fiber composite sidewalls and baseplate
- Aluminum basket
- Adhesively bonded and bolted

## *Schedule*

| Milestones        | FY11 | FY12 | FY13 | FY14 | FY15 | FY16 |
|-------------------|------|------|------|------|------|------|
| Contracting       |      |      |      |      |      |      |
| Trade Study       |      | 4    |      |      |      |      |
| Tech Development  |      |      | 5    |      |      |      |
| Detailed Design   |      |      |      |      |      |      |
| Manufacturing     |      |      |      |      |      |      |
| Test & Evaluation |      |      |      |      |      | 6    |

Milestone Indicators:



Milestone Timeline:

# Advanced Vehicle Power Tech. Alliance (AVPTA)



Advanced Combustion  
Engines and  
Transmissions

Lightweight Structures  
and Materials

Energy Recovery and  
Thermal Management

Alternative Fuels and  
Lubricants

Hybrid Propulsion  
Systems & Energy  
Storage

Analytical Tools

## Technical areas for joint activity:

- High density, energy efficient powertrain

- Extreme gains in engine efficiency

- ❖ Ignition Models for Heavy Hydrocarbon Fuels

- Reduce weight to improve performance

- Cost reduction for consumer market

- ❖ Lightweight vehicle structures
- ❖ Multi-Material Joining

- Cost Improved efficiency, manage heat generation

- Efficiency gains through waste heat recovery

- ❖ Thermoelectrics and Enabling Engine

- Standardization & security

- Efficiency gains through advanced oil formulations

- ❖ Fuel Bulk Modulus

- Efficiency improvements

- ❖ Computer Aided Engineering for Batteries (CAEBAT)
- ❖ Non-Rare Earth Materials for Motors

- Assessment/ Design Trades



Driving results through collaboration

## Similar Goals

Lighter Weight Vehicles

## Similar Materials

AHSS

Aluminum

Composites

## Similar Applications

Ground vehicles / Structures

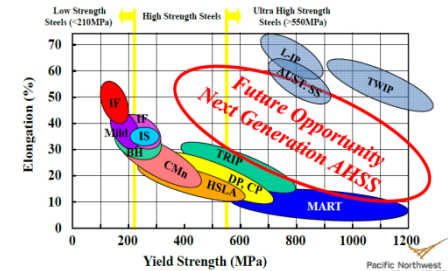
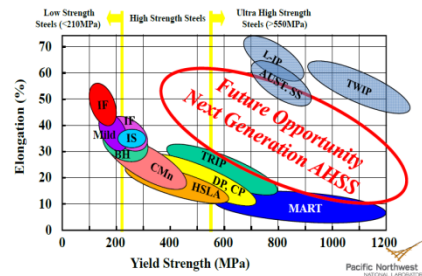
Diesel engines

## Similar Manufacturing Processes

Welding (Friction stir, MIG/TIG)

Forming (hot stamping)

Castings



Given the similarities, it makes sense to collaborate.

# Big Differences



| <u>DOE (automotive)</u> |                           |  | <u>ARMY (defense)</u> |  |
|-------------------------|---------------------------|--|-----------------------|--|
| Vehicle Weight          | ← 2T vs. 70T →            |  | Vehicle Weight        |  |
| Design                  | ← Unibody vs. Monocoque → |  | Design                |  |
| Material Char.          | ← Thin vs. Thick →        |  | Material Char.        |  |
| M & S                   |                           |  | M & S                 |  |
| Mfg. Process Dev.       | ← High vs. Low vol. →     |  | Mfg. Process Dev.     |  |
| Mfg.                    |                           |  | Mfg.                  |  |
| Testing                 | ← Crash vs. Blast →       |  | Testing               |  |

Given the differences in programs, business environment, technical details, and funding timing, one must take a very detailed, task by task examination of collaboration areas.

# Ballistic Shock Test



# Dissimilar Material Joining



- **Definition**: Joining of any material combination that cannot be arc welded.
- Example: Some 70XX aluminum cannot be arc welded.

## CVP HFBC Relevant Joining Technology

| Criteria             | Arc Welding              | FSSW    | Bi-metallic Plates | Mechanical (bolts) | Adhesives |
|----------------------|--------------------------|---------|--------------------|--------------------|-----------|
| Dissimilar Materials | <b>X<br/>(weld wire)</b> | ✓       | ✓                  | ✓                  | ✓         |
| Strength             | ✓                        | ✓?      | ✓?                 | ✓?                 | <b>X?</b> |
| Corrosion            | ✓                        | ✓       | ✓                  | X?                 | ✓         |
| Repairability        | ✓                        | ?       | ✓?                 | ✓                  | ✓?        |
| Cost (per foot)      | \$1X                     | \$0.5X* | \$2X+              | \$                 | ?         |
| No 2nd Projectile    | ✓                        | ✓       | ✓                  | X                  | ✓         |

### **Major Factors:**

Material  
Thickness  
Joint Design  
Process specific



Metals

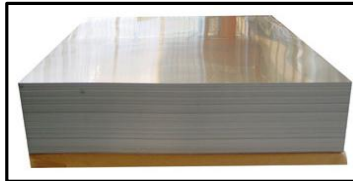
Metals &  
Composites

Composites

# Project Technologies



|   | Weld Wires                     | Solid State                  | ARC Weld                  | Mechanical               | Misc Process            | Misc Project |
|---|--------------------------------|------------------------------|---------------------------|--------------------------|-------------------------|--------------|
| Mg  |                                | 1                            |                           | 1                        |                         | 1            |
| Al  | 1                              | 1                            |                           |                          | 1                       |              |
| AHSS  | 2                              | 4                            | 2                         |                          | 1                       | 1            |
| FRC   |                                |                              |                           | 3                        | 1                       | 1            |
| <br> | AHSS weld wire                 | Hi Speed<br>AL FSW<br>MG FSW |                           | MG SP<br>Rivets          | Breakthru               | MIFERD       |
|   | AHSS weld wire<br>Al weld wire | FSW<br>SFSW<br>TFSW<br>FAW   | Weld Model<br>Weld Char'n | Adh Bolt + Adh Bolt load | LACS Infusion Breakthru | Auto Join TS |

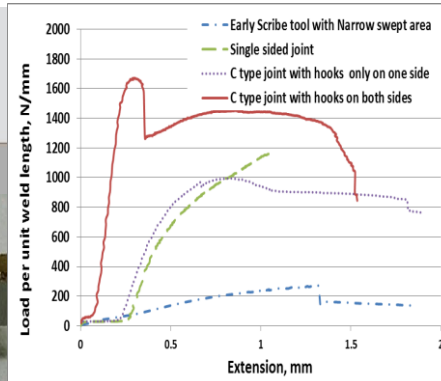
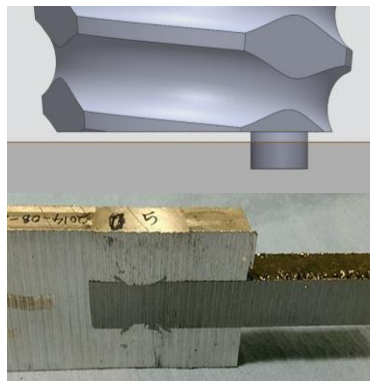


## AHSS WELDWIRE

- Excessive weld cracks in vehicles due to fatigue, not ballistics.
- Failure analysis identified hydrogen embrittlement as major culprit.
- New AHSS weld wire developed that can deal with hydrogen embrittlement.
- Current status: Weld wire produced.
- **Next steps**: Create welded samples and evaluate.
- **Verdict**: Depends on evaluation
- **Performer**: ORNL

## HIGH STRENGTH AL 6XXX WELDWIRE

- 6xxx alloys are attractive from a cost, and performance standpoint: 15-20% strength increase. But, 5556, 5183, 5356 filler alloys are not compatible with high strength 6xxx alloys due to weld cracks.
- New weld wire solves  $MgSi_2$  brittle effects of using 4043 in high strength 6xxx alloys. Enables joining 6xxx alloys (6055) to each other and to 5xxx alloys (5083)
- Current status: Weld wire does not meet corrosion requirements.
- **Next steps**: Chemistry optimization to minimize corrosion susceptibility. Weld samples and evaluate ballistics.
- **Verdict**: Depends on evaluation in late FY16.
- **Performer**: Alcoa



## SCRIBE FSW

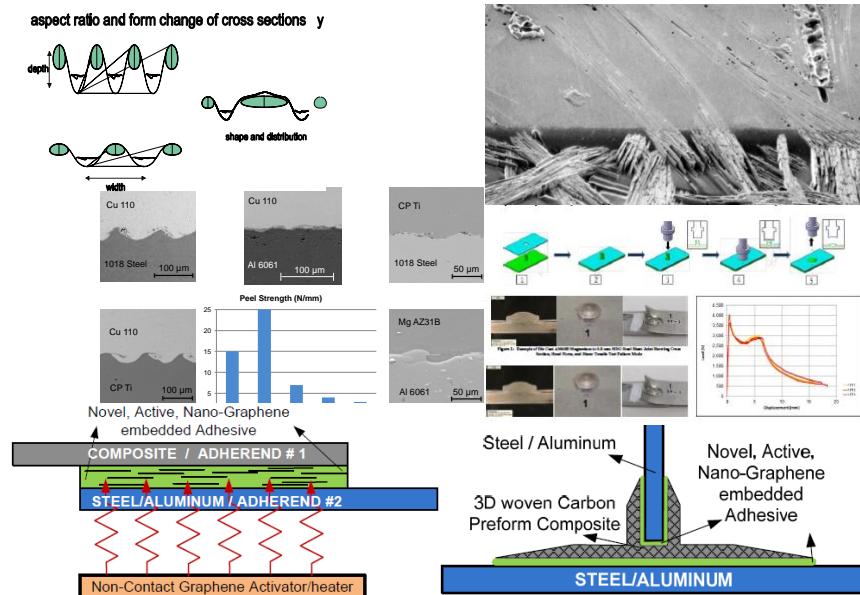
- Have developed SFSW to penetrate up to 1" thick Aluminum
- Joint strength from single pass is too low. Doubles for in plane double pass.
- Working on joint designs and multiple pass method to increase joint strength
- Have not evaluated ballistic shock or corrosion
- **Next steps**: Create welded samples and evaluate.
- **Verdict**: Depends on evaluation
- **Performer**: PNNL

## THERMAL FSW

- Have developed process to weld 0.5" thick welds with 105% joint strength of comparable aluminum welds.
- Tool life is short and tool is expensive.
- Working on thermal control through water cooled fixtures to extend tool life (weld length).
- Have not evaluated ballistic shock or corrosion
- **Next steps**: Create welded samples and evaluate.
- **Verdict**: Depends on evaluation
- **Performer**: Focus Hope

# Breakthrough Techniques in Dissimilar Material Joining

POC: William Joost, Richard Gerth



## Schedule & Milestones

| MILESTONES           | FY14 | FY15 | FY16 | FY17 | FY18 |
|----------------------|------|------|------|------|------|
| Breakthrough Joining |      |      |      |      |      |
| Michigan State       | 2    |      | 3    |      |      |
| Johns Hopkins        | 2    |      |      |      | 4    |
| Ohio State           | 2    |      | 3    |      |      |
| Chrysler             | 3    |      | 4    |      |      |
| Oak Ridge            | 3    | 4    |      |      |      |

Milestone Indicators: TRL or SRL: Significant Activities:

## Problem Statement:

- A weight optimized vehicle is a multi-material structure, where the best material is used to meet the performance requirements at every location.
- Current processes are focused on various welding technologies, preheating technologies, adhesives, mechanical joints, and explosive bonding (bi-metallic plates).
- This project is investigating novel techniques that are significantly different than current technologies and are applicable to thin sheet and thick plates.

## Product(s):

- Active, Tailorable Adhesives for Dissimilar Material Bonding, Repair and Reassembly (Michigan State)
  - Electro-magnetically cure and un-cure adhesives
- Brazing Dissimilar Materials with a Novel Composite Foil (Johns Hopkins)
  - Self propagating brazing foil with minimal surface prep
- Welding of Dissimilar Materials by Vaporizing Foil Actuator (Ohio State)
  - Electrically vaporizing material into a rapidly expanding plasma to explosively bond dissimilar metals (Cu, Mg, AHSS, Al)
- Upset Protrusion Joining (Chrysler, AET)
  - Integrated "rivets" cast into Mg part and mechanically joined to steel.
- Laser-Assisted Joining Process of Aluminum and Carbon Fiber Components (Oak Ridge)
  - Carbon fiber composite micro-surface prepping process to increase adhesive bonding with Aluminum.

## Payoff: (BOTH military & commercial)

- Potential for lower cost and more effective methods for joining dissimilar materials, thereby accelerating the adoption of lighter weight materials in military and commercial vehicles. These technologies are applicable to thin sheet and thick plate.

## Cooperative Research and Development Agreement (CRADA)

- Established between federal labs and commercial, academic or nonprofit partners to facilitate technology transfer between the parties for mutual benefit
  - GM Fuel Cell

## Test Service Agreement (TSA)

- Is a technology transfer mechanism that enables federal laboratories to perform work for hire.
  - Dodge Truck Testing on the Vehicle Inertial Properties Evaluation Rig (VIPER)

## Small Business Technology Transfer (SBR, STTR)

## Pathways to TARDEC

- Ground Vehicle Gateway: <https://tardec.groundvehiclegateway.com>
- TARDEC Industry Day
- Defense Mobility Enterprise (DME): <http://defensemobility.org/>